SPACECRAFT ORBITAL MECHANICS ANALYSIS

FOR INTERCEPTION SERVICE

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At present time about 6120 asteroids are discovered, they are catalogued and have reliably determined elements of orbits. About 17 thousands asteroids are discovered, but they have not reliably determined orbits. In a main asteroid belt between a Mars and Jupiter is concentrated 99,8 % of asteroids.

Among asteroids outside of a main belt group of bodies, approaching with the Earth, is the most important forus. Quantity of such asteroids with the size more than 1 km is estimated in 1700 - 2200 bodies (on data T. Gerels, USA). Asteroids of Amor, Appolo and Aton group have name near - Earth asteroids. These asteroids can come nearer to the Earth less than on 45 mln. km. If to accept, that the distribution near - Earth asteroids by sizes is close to distribution of small-sized asteroids of a main belt, we shall receive the following estimations of quantity near - Earth asteroids:

Diameter of bodies

Diameter of bodies	near - Earth
>1 km	2000
>100 m	200 thousand
>50 m	800 thousand

If to take into account, that the asteroids are distributed in tube with diameter 1 a. u., easily to receive, that in a vicinity of the Earth with radius 1 mln. km one asteroid appearls on the average in 2,5 days from number potentialy dangerous bodies with the size of 50 m.

Asteroids, the orbits of which are located near to an Earth orbit have small values of the asimptotic approach velocity (0 - 3 ...5 km / m). Small relative velocities of such asteroids permit to have a large reserve of time before expected collision, however they approach with the Earth from any direction practically with equal probability. Therefore for their timely detection it is necessary to carry out scanning of whole celestial sphere. Other important peculiarity of such asteroids is the fact, that for them the cross section of capture it can be more than diameter of atmosphere of the Earth (effect of the gravitational pressing for trajectories), fig. 1.

Other dangerous space objects (DSO) can be divided into two groups:

- DSO, orbits of which pass between orbits Mercury and Jupiter;
- DSO, perihelions of orbits of which lay inside an orbit of the Earth, and apoceuter lay at an orbit of the Jupiter or Pluto.

On fig. 2 are shown curves of possible relative velocities of approaching

DSO with the Earth for both above mentioned groups. It is visible, that the asteroids of the first group have maximum velocities of approaching from 8 up to 28 km / m, and asteroids of the second group - from 32 up to 71 km / m.

The possible variants of collision DSO with the Earth are shown on fig. 3.

For detection of asteroids and comets can be used optical, infrared and ultra violet telescopes of ground and space basing. Therefore the ground-space service of detection should form in view of an optimum combination of their opportunities.

It is necessary to note, that accommodation of telescopes in space will make their independent from weather and will allow to decide a problem of detection DSO coming nearer on the part of the Sun. It is for this purpose possible to place S/C with a telescope in a point libration L1 the sun - Earth system were between the Sun and Earth on distance 1,5 mln. km [1]. It will ensure a reserve of time more days, at velocity of approaching V=1 7 km / m.

Space segment of a service of detection of asteroids will include in self a little S/C with telescopes, working on near - Earth and heliocentric orbits (fig. 4). For detection DSO coming nearer on the part of the Sun it will be possible to place 1-2 S/C in a point libration L1, and then and on other heliocentric orbit in a vicinity of the Earth, and on large distances, for example in points libration L4 and L5, located on distances in 150 mln. km from the Earth. It will allow with significant forestalling to find out DSO.

On fig. 5 boundaries of interception DSO on interplanetary trajectories are resulted. Times of flight in given points of a meeting are determined from the moment of start S/C from an Earth parking orbit in height of 200 km.

The boundaries resulted on fig. 6 of interception on interplanetary trajectories are given for case of velocity of start from a basic orbit in 4 km / m. It is visible, that for interception on distance 40 thousand km (the range of a geostationary orbit) is required 6 hours, and in region of an orbit of the Moon 4 days.

Proceeding from available time of achievement of a boundary of interception, easily to determine from fig. 7 detection required to range DSO depending on their velocity of approach to the Earth. Than it is less interval of time between start and interception, that large velocity is necessary for informing S/C, that is shown on fig. 8 and 9.

For a withdrawal DSO with getting in the Earth of a trajectory that smaller change of its speed is required, than on greater distance it will be carried out.

As an example it is possible to estimate power expenses for a withdrawal of asteroid with getting trajectories in days before collision with the Earth. Velocity required to a lateral pulse will in this case make 100 m/s. For asteroid by a diameter 100 m, type consisting of a material basalt, it will correspond to energy of the order 1013 j. Such energy is allocated at explosion nuclear charge by capacity of 2 kt. Were available data show also, that for destruction basalt asteroid the diameter 500 m require charge by capacity 3-5 mt. Weight such charge will make about 3 tons, that lays within the limits of opportunities on insertion payload by the modern LV.

The results of lead design-ballistic studies show a technical opportunity of creation of a service of protection of the Earth from dangerous space objects within the framework of wide international cooperation [2].

Literature:

1. J. V. Smith " Protection of the human rase against natural hazards (asteroids, comets, volcanoes, earthquakes). Geology, v.13, p. 675-678, 1985.
2. V. M. Kovtunenko, A. V. Zaitsev, V. A. Kotin " Technological aspects and problems of creation of system of protection of the Earth from dangerous space objects "
SPE-94, on September 26-30, 1994, Sneszinsk.

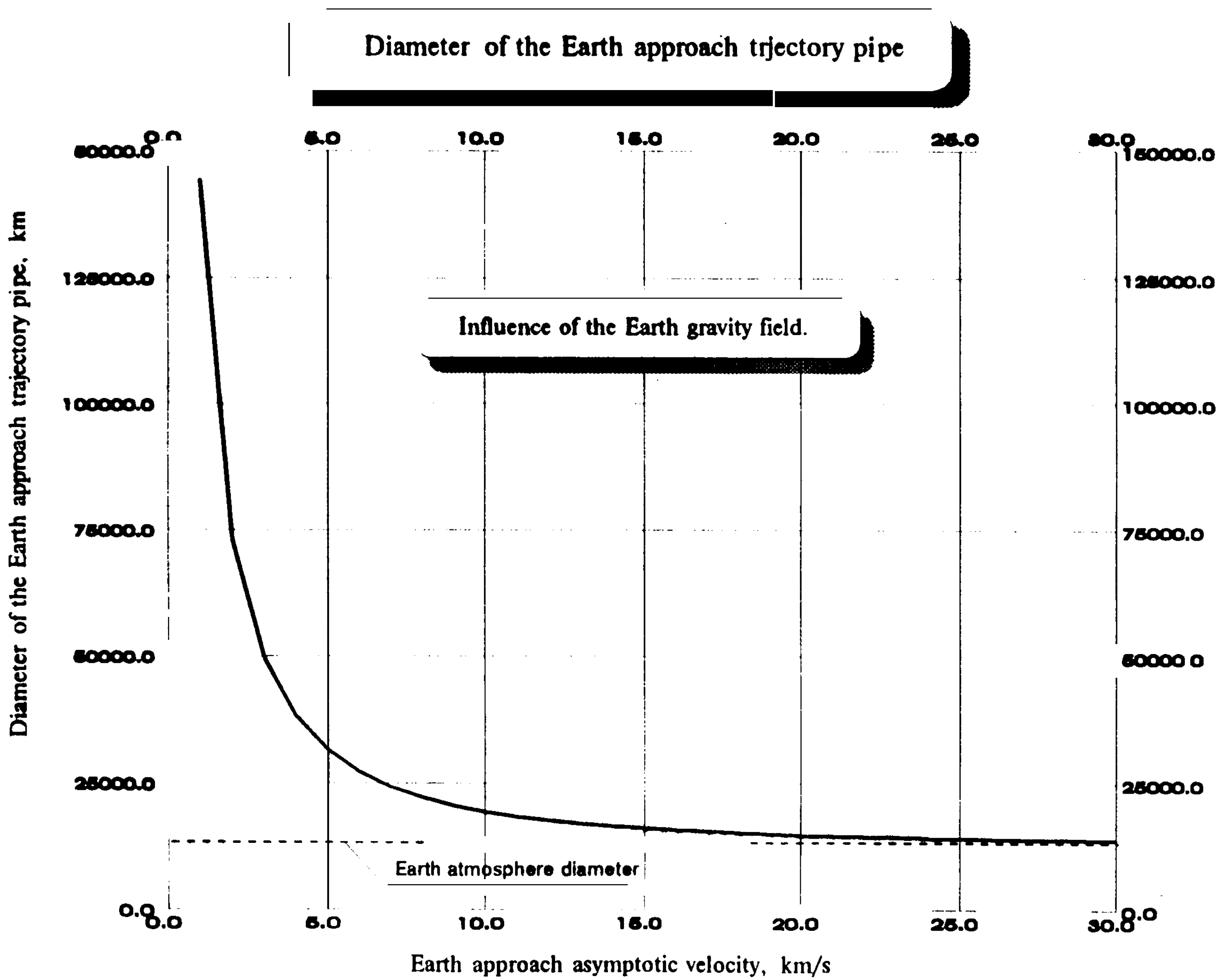

Diameter of the Earth approach trjectory pipe
Influence of the Earth gravity field.
Diameter of the Earth approach trajectory pipe, km
150000.0
125000.0
100000.0
75000.0
50000.0
25000.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Earth atmosphere diameter
Earth approach asymptotic velocity, km/s

Fig 1

Possible re ative velocity for col ision DSO with Earth

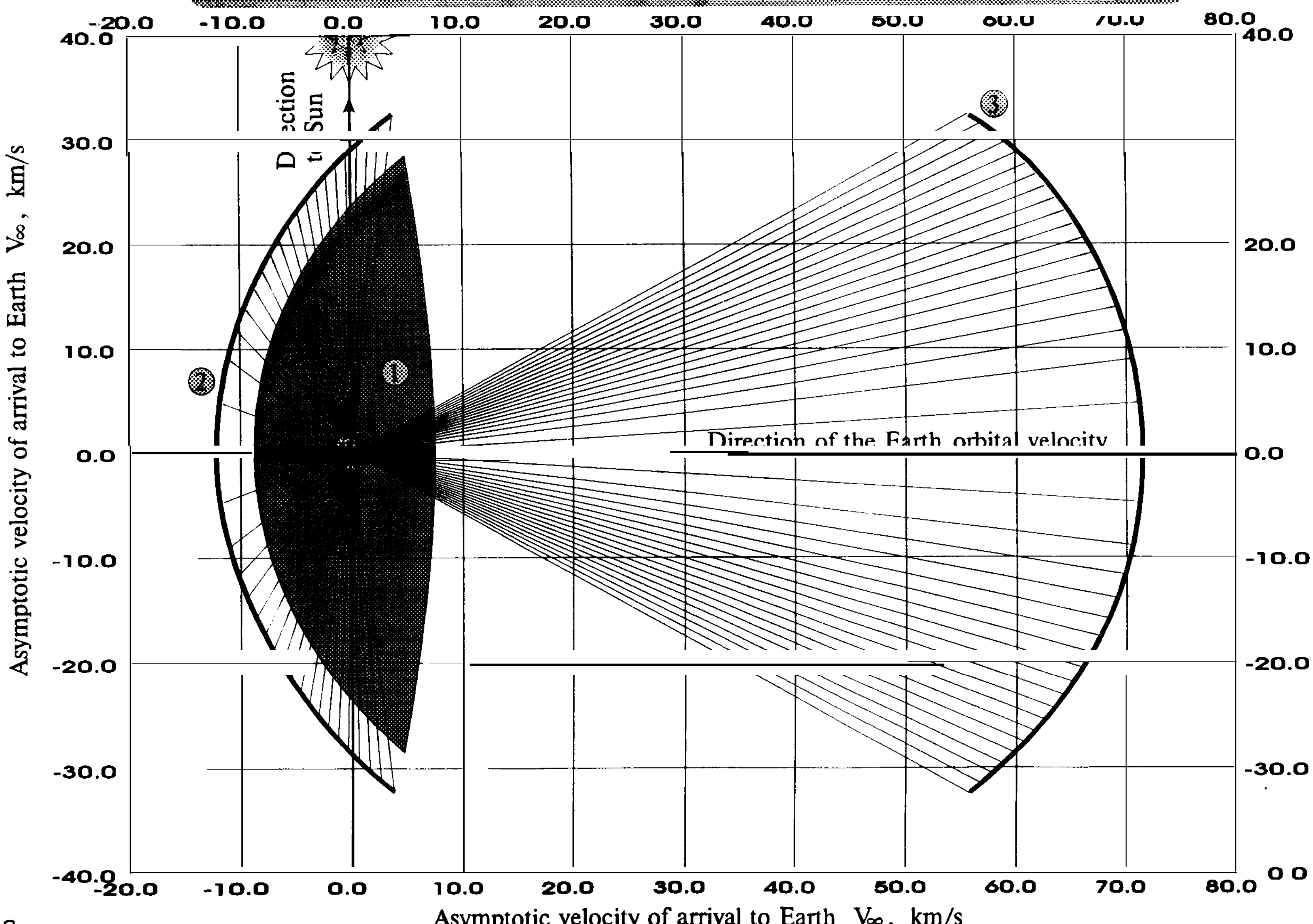
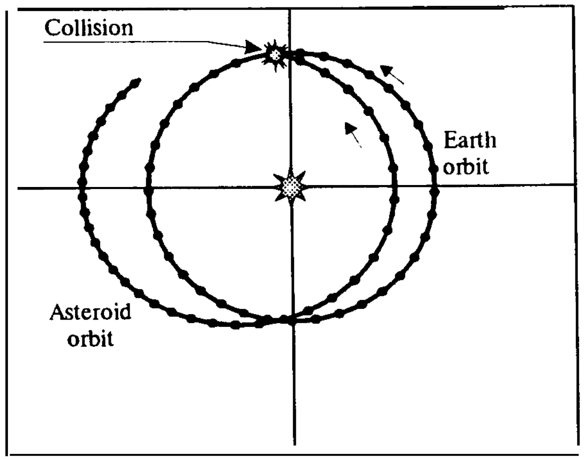


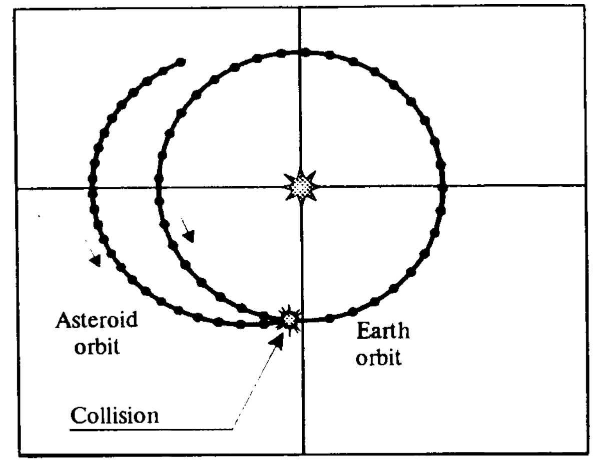
Fig. 2

Possible options of collision with Dangerous Space Objects (DSO)

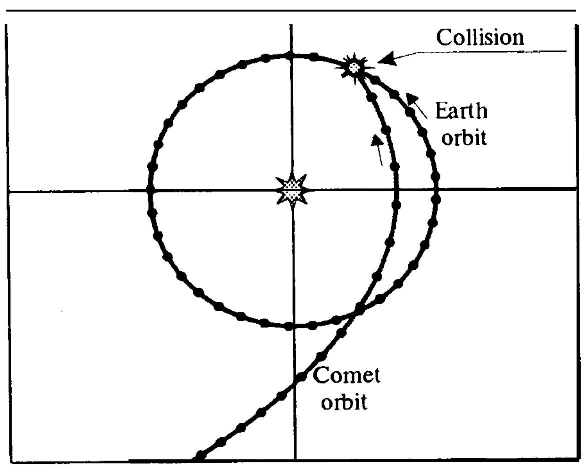
Time ticks - 10 days



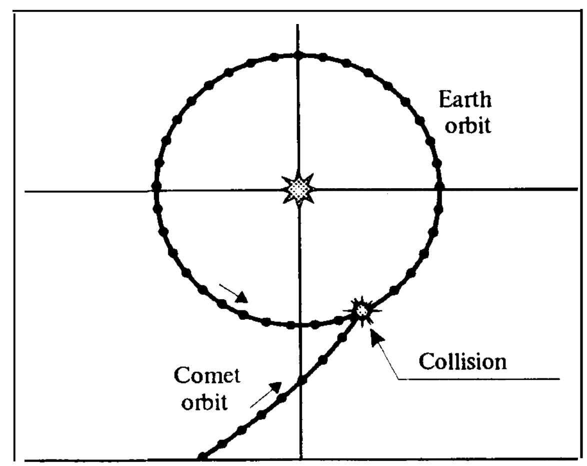
Collision with asteroid, moving from perihelion



Collision with asteroid, moving to perihelion



Collision with comet, moving from perihelion



Collision with comet, moving to perihelion

Fig 3

SPACE OBSERVERS POSITION

ON THE HALO-ORBIT AROUND LIBRATION POINT L1

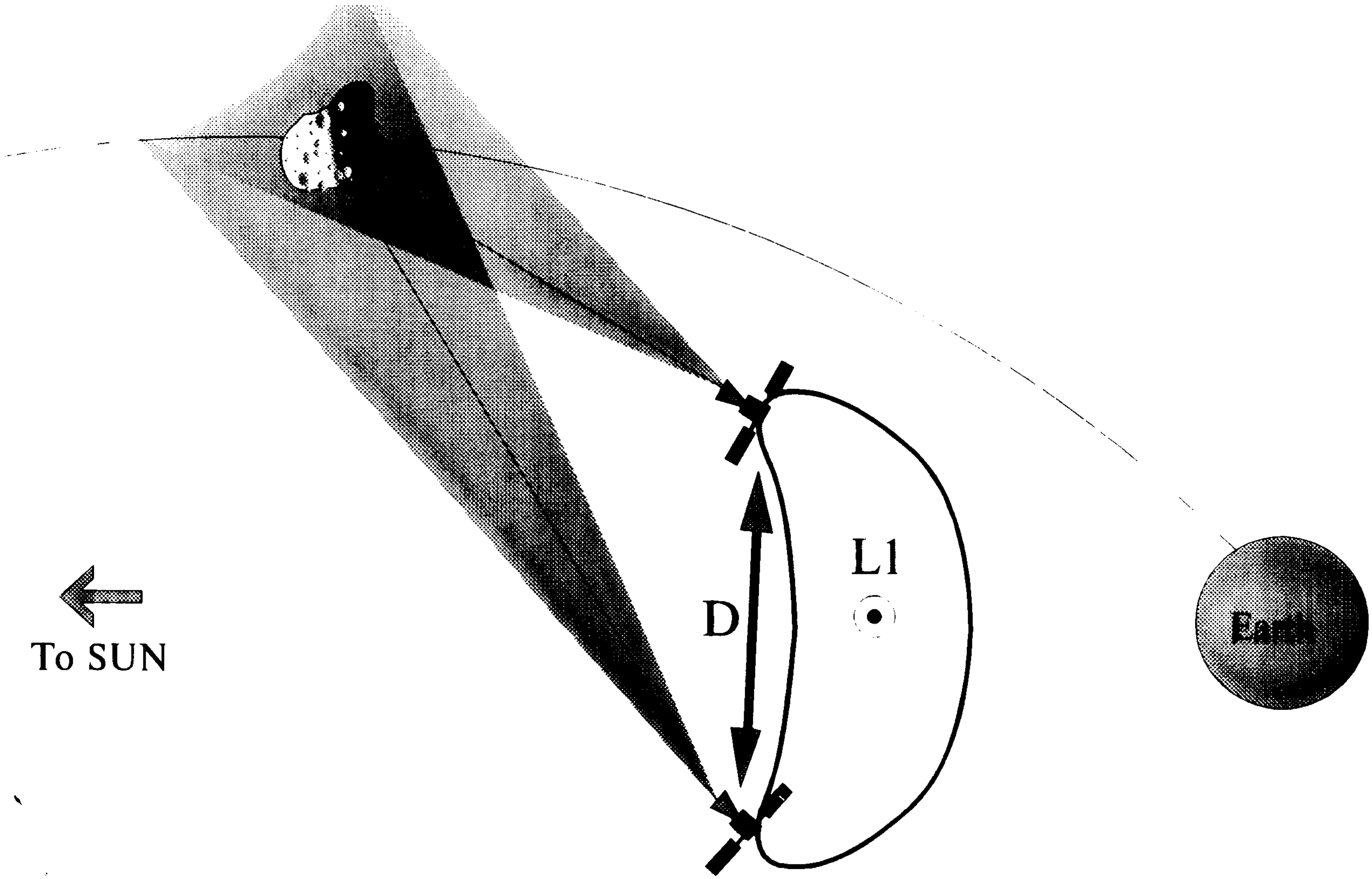


Fig. 4

INTERCEPTION TIME VS DISTANCE

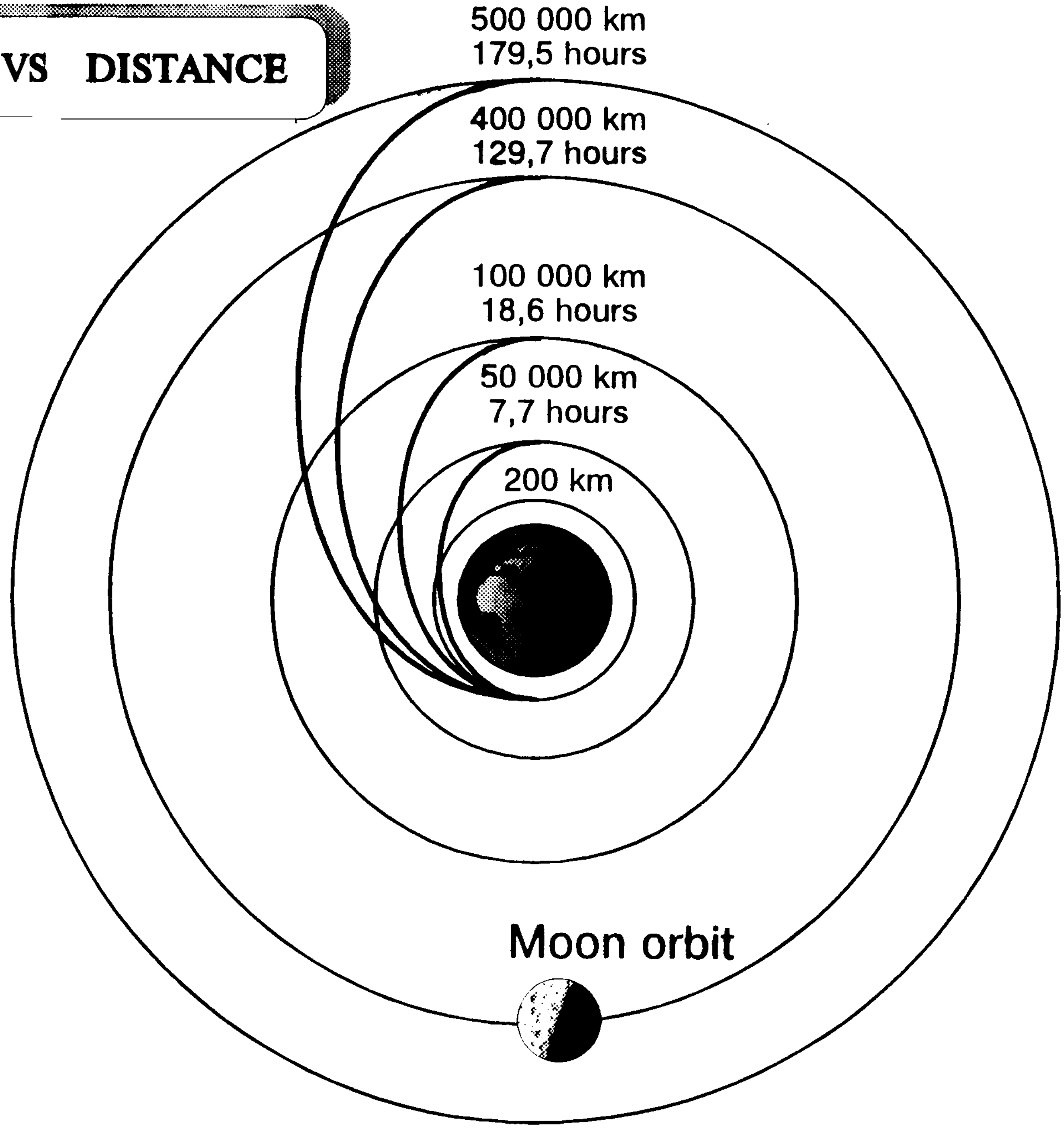


Fig. 5

Boundary of zone which can be reached during different time (days)
(Earth departure velocity is 4 km/s)

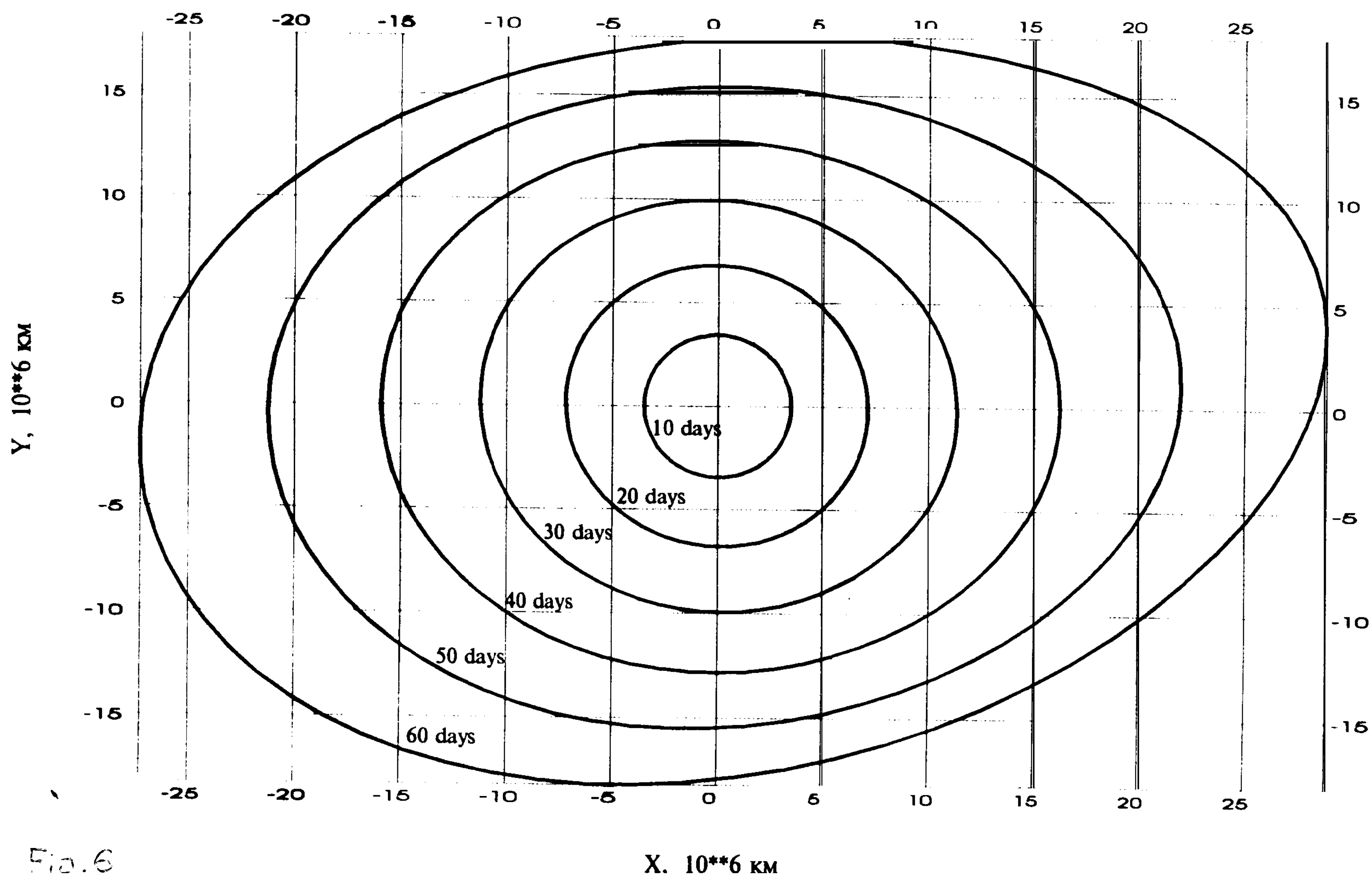


Fig. 6

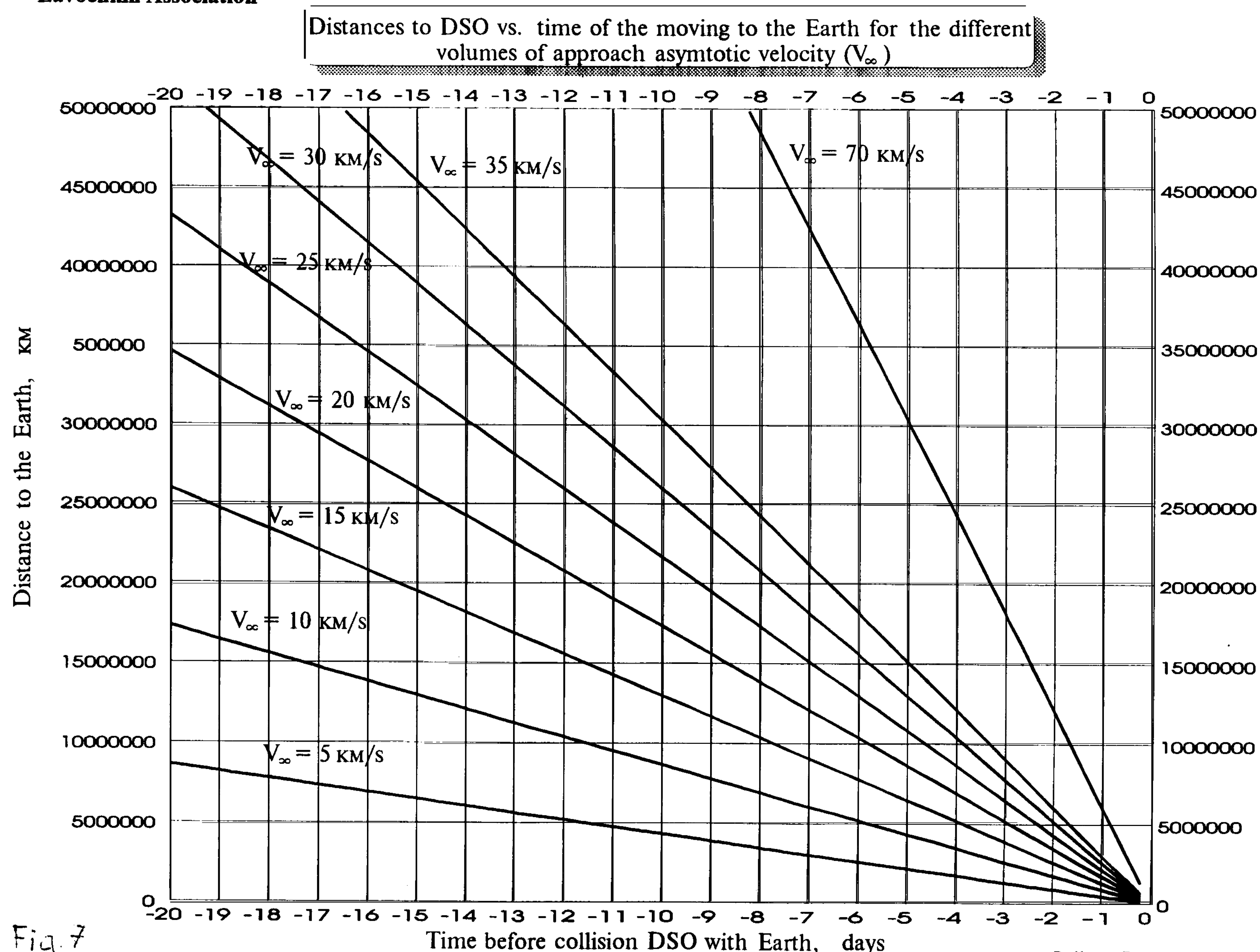

Distances to DSO vs. time of the moving to the Earth for the different volumes of approach asymtotic velocity (V_∞)
V_∞ = 30 KM/s
V_∞ = 35 KM/s
V_∞ = 70 KM/s
V_∞ = 25 KM/s
V_∞ = 20 KM/s
V_∞ = 15 KM/s
V_∞ = 10 KM/s
V_∞ = 5 KM/s
-20 -19 -18 -17 -16 -15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
50000000
45000000
40000000
500000
30000000
25000000
20000000
15000000
10000000
5000000
0
35000000
Distance to the Earth, KM
Time before collision DSO with Earth, days

Fig. 7

Required velocity for time of the launch
(Interception time is -30, -10, -2 days)

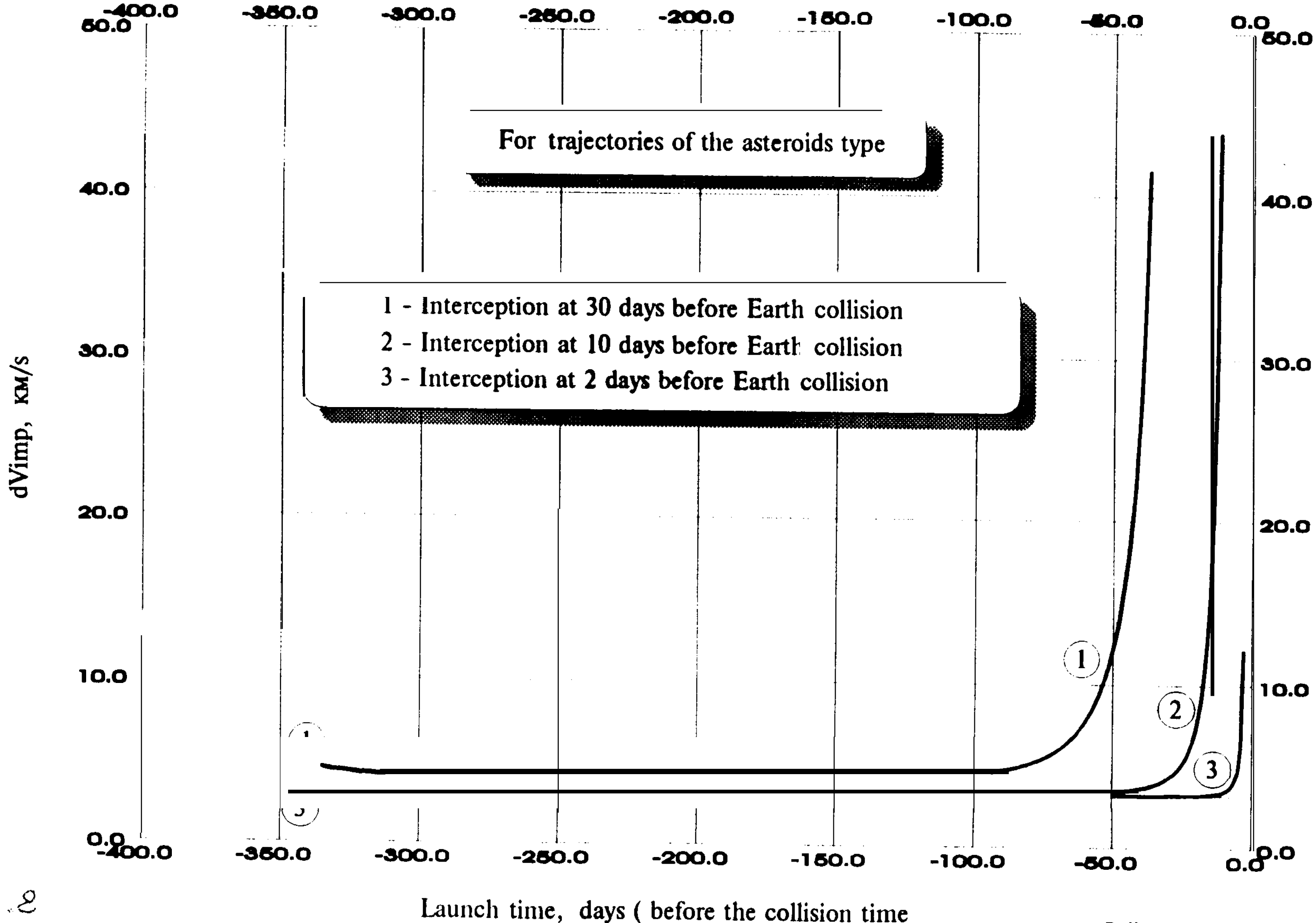


Fig. 8

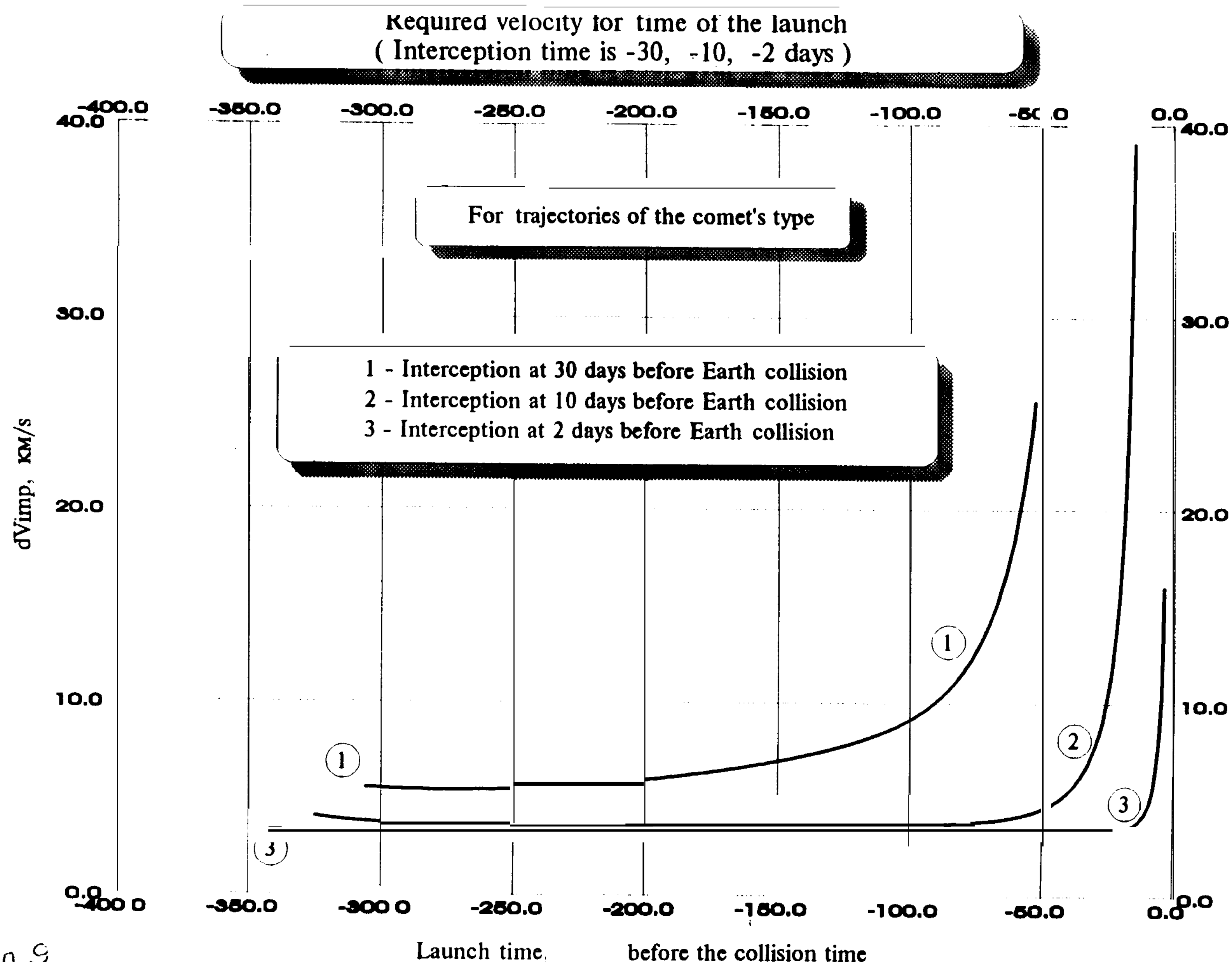

Required velocity for time of the launch
(Interception time is -30, -10, -2 days)
For trajectories of the comet's type
1 - Interception at 30 days before Earth collision
2 - Interception at 10 days before Earth collision
3 - Interception at 2 days before Earth collision
dVimp, KM/s
40.0
30.0
20.0
10.0
0.0
-400.0
-350.0
-300.0
-250.0
-200.0
-150.0
-100.0
-50.0
0.0
1
2
3
Launch time, before the collision time

Fig 9